Control The Flow Of Water in Multi Storey Building

Ashish Aher, Ruturaj Chinchani, Kunal Chopde, Girish Bhide

Abstract - Roof tank solutions were originally created more than a century ago, as buildings grew taller and taller. The required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building. Moreover, reliable and efficient pumps for pressurised systems were not available. The immediate solution was to use standard pumps to lift the water to the tank. From the tank, gravity ensured a natural downwards flow and sufficient pressure. The use of roof tanks to ensure adequate water pressure in buildings, and especially tall buildings, is very common. The alternative to roof tanks is the use of pressurised systems, where a number of booster pumps provide the necessary pressure.

Index Terms - booster pumps, energy saving, pressurized system, single booster system, series connected system, zone divided system, roof tank system.

1 INTRODUCTION

THE use of roof tanks to ensure adequate water pressure in buildings, and especially tall buildings, is very common. The alternative to roof tanks is the use of pressurised systems, where a number of booster pumps provide the necessary pressure. The analysis includes a roof-top system and four different pressurised system configurations. Roof tank solutions were originally created more than a century ago, as buildings grew taller and taller. The required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building.[1] To maintain the same pressure and flow rate throughout the building. Maintaining the same pressure throughout the building with the help of boosters also maintaining same discharge at all floors. Reducing the load over the building by removing the roof tank. Moreover, reliable and efficient pumps for pressurised systems were not available. The immediate solution was to use standard pumps to lift the water to the tank. From the tank, gravity ensured a natural downwards flow and sufficient pressure. Despite improved and energy-efficient pressure booster technology, many buildings still have roof tanks.[2]

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2 LITERATURE REVIEW

Roof tank solutions were originally created more than a century ago, as buildings grew taller and taller. The required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building. Moreover, reliable and efficient pumps for pressurized systems were not available. The immediate solution was to use standard pumps to lift the water to the tank. From the tank, gravity ensured a natural downwards flow and sufficient pressure. Despite improved and energy-efficient pressure booster technology, many buildings still have roof tanks.[2]

2.1 Current scenario

Roof tanks allow the users to have both water pressure and water supply in situations where there is no electrical power. Roof tanks vary greatly in size, but common to them all is that they feature "water at the ready", storing water for domestic purposes and fire-fighting. The simple construction basically entails a tank, inlet and discharge piping, a float switch, and a pump. When the water level in the tank drops below a certain level, the float switch engages the pump, refilling the tank.[1]

The establishment and usage of roof tanks is often deeply rooted in local traditions. Several cities and geographical areas around the world still employ roof tanks, and will continue to do so for years. An estimated 15,000 roof tanks dot the skyline, forming an integral part of the city's water supply system. In all over the India roof tanks are very common as well. In other countries like America, Europe, roof tanks are employed much less, where instead pressurised systems are primarily chosen. Numerous types of pressurised system configurations are available, each having its own pros and cons. Common to the different types of pressurised system, is less of a demand for space and lower life cycle cost. However from a functional point of view, roof tanks of today work adequately in many aspects. The technology is mature, and operation is stable. The user receives the water pressure required. On the negative side, roof tanks involve elements that are not always desired. Examples include higher capital costs due to the tank set-up and greater structural requirements, high operating costs, a lack of pressure control, and difficulty in maintaining the roof tank itself.[2]

2.2 Booster Pumps

Booster pump is a machine which will increase the pressure of a fluid, generally a liquid. It is similar to a gas compressor, but generally a simpler mechanism which often has only a single stage of compression, and is used to increase pressure of an already pressurised gas. Booster pumps are usually piston or plunger type compressors. A single-acting, single-stage booster is the simplest configuration, and comprises a cylinder, designed to withstand the operating pressures, with a piston which is driven back and forth inside the cylinder. The cylinder head is fitted with supply and discharge ports, to which the supply and discharge hoses or pipes are connected, with a non-return valve on each, constraining flow in one direction from supply to discharge. When the booster is inactive, and the piston is stationary, gas will flow from the inlet hose, through the inlet valve into the space between the cylinder head and the piston. If the pressure in the outlet hose is lower, it will then flow out and to whatever the outlet hose is connected to. This flow will stop when the pressure is equalised, taking valve opening pressures into account.[3]
Once the flow has stopped, the booster is started, and as the piston withdraws along the cylinder, increasing the volume between the cylinder head and the piston crown, the pressure in the cylinder will drop, and gas will flow in from the inlet port. On the return cycle, the piston moves toward the cylinder head, decreasing the volume of the space and compressing the gas until the pressure is sufficient to overcome the pressure in the outlet line and the opening pressure of the outlet valve. At that point, the gas will flow out of the cylinder via the outlet valve and port.[4]
There will always be some compressed gas remaining in the cylinder and cylinder head spaces at the top of the stroke. The gas in this "dead space" will expand during the next induction stroke, and only after it has dropped below the supply gas pressure, more supply gas will flow into the cylinder. The ratio of the volume of the cylinder space with the piston fully withdrawn, to the dead space, is the "compression ratio" of the booster, also termed "boost ratio" in this context. Efficiency of the booster is related to the compression ratio, and gas will only be transferred while the pressure ratio between supply and discharge gas is less than the boost ratio, and delivery rate will drop as the inlet to delivery pressure ratio increases.[3]
Delivery rate starts at very close to swept volume when there is no pressure difference, and drops steadily until there is no effective transfer when the pressure ratio reaches the maximum boost ratio.
Compression of gas will cause a rise in temperature. The heat is mostly carried out by the compressed gas, but the booster components will also be heated by contact with the hot gas. Some boosters are cooled by water jackets or external fins to increase convectional cooling by the ambient air, but smaller models may have no special cooling facilities at all. Cooling arrangements will improve efficiency, but will cost more to manufacture.
Boosters to be used with oxygen must be made from oxygen-compatible materials, and use oxygen-compatible lubricants to avoid fire.[3]
2.3 Hygienic aspects in roof tank
In addition to serving as a storage device and creating pressure, roof-top tanks unfortunately can also serve as breeding grounds for bacteria constituting a major health risk. The exceptionally resistant bacteria Legionella often appears as an unwelcome guest in water systems. In order to survive, the habitat for Legionella and other micro-organisms arises in the bio-film created in the water system. Bio-film is created inside pipes and water tanks, serving as a protective barrier and breeding ground for the bacteria. If the water tank is made of an organic material such as wood, the tank itself serves as food stock for bacteria during its entire lifetime. Regular cleaning and maintenance of water tanks in many countries is required by law, so the additional costs, including disinfection, should also be taken into consideration.[2]

3 Objective of the Present Work

Like buildings, booster systems vary greatly in size and design, making it difficult to determine which is most efficient. In this fictitious case study, let's look at four different system configurations. Which is the most economical choice in this example?

- Single booster system
- Zone-divided system
- Roof tank system
- Series connected system

4 Types of System

1. Single booster system:-

A water tank is placed in front of the pump system and filled with water from the mains. This allows the capacity of the mains to be lower than the building's peak demand, ensuring constant pressure even in peak flow situations. The break tank is filled with water during low consumption periods and ensures a uniform water supply to the booster pumps at all times.

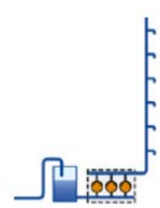

Fig.1 Single booster system

2. Zone-divided system:-

The supply system is split into several zones supplying a maximum of 12 floors each. This ensures adequate water

ISSN 2229-5518

pressure on all floors without using pressure relief valves. The minimum pressure on the upper floor in each zone is kept at 1.5 - 2 bar. The maximum pressure on the lowest floor in each zone does not exceed 4 - 4.5 bar.

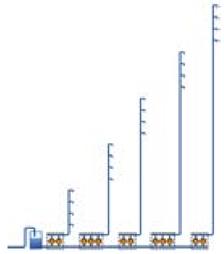

Fig.2 Zone-divided system

3. Roof tanks system:-

This ensure both water pressure and water supply in case of power failure. This solution requires pressure reduction valves on each floor in order to avoid undesired high static pressures at the tap, which creates unacceptable noise while tapping. In this model the upper six floors require a separate booster system in order to create sufficient pressure. The static pressure there is too low due to the insufficient geometric height to the roof tank.

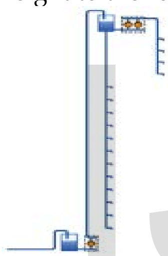

Fig.3 Roof tank system

4. A series-connected system

This enables an effective usage of power because the water is only pumped to the zone where it is used and not past it. However, complete control is very important. When a consumer draws water on the upper floors, the booster systems must deliver the water from the bottom of the building.

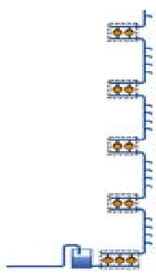

Fig.4 Series connected system

5 Design Considerations of System

- Pressure of the system = 0.5 to 3bar[6]
- Flow rate of tap water = 12 – 20 lit./min[6]

5.1 Selection of system

From above comparison we have selected
“Series Connected System”
to achieve our objective which is beneficial and economical.
System type - Series connected system
Type of Pump- Reciprocating Pump
Manufactured by- Grundfos Commercial Building Services[5]
Power consumption Of Pump- 40-120 Watt
Phase of Pump :- Single Phase
Operating Head - 6m
Flow Of Pump- 16.25 lit./min
Pressure range - 0.5 bar to 9 bar
Operating temperature of fluid- 0ºC to 90ºC

Fig. 5 Booster Pump

5.2 Selection of pipe

Type of pipe- PVC
Outer diameter Of pipe - 44 mm[6]
Wall thickness of pipe - 40 mm[6]

6 Working of System

6.1 Working of the System due to Gravity

Water is supplied to system due to gravity. When water from the roof tank is flow through piping just due to gravitational force acting on it.
But due to gravitational force water first reached to lowest level i.e. nearest to ground level. Thus due to this phenomenon other level of piping gets low pressure and low flow rate.

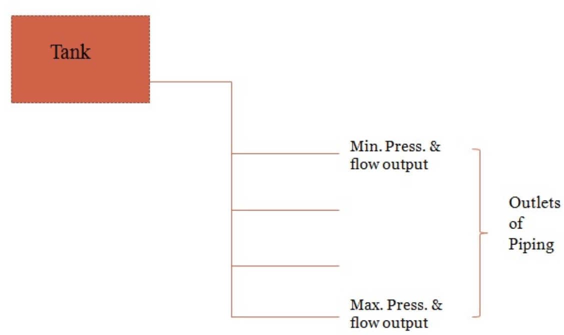

Fig.6 Block Diagram of the system with Gravitational force

6.2 Working of Pressurized system

Water supplied with Booster system Using booster system flow and pressure of piping system is maintain at constant value. Thus to achieve objective booster pump is introduced in piping assembly. Booster pump is selected with particular specification

Introducing pump in piping where pressure and flow rate is low. By using this pump water in line is maintained to its properties. Pump only works when pipe line will undergoes pressure drop and low flow rate.

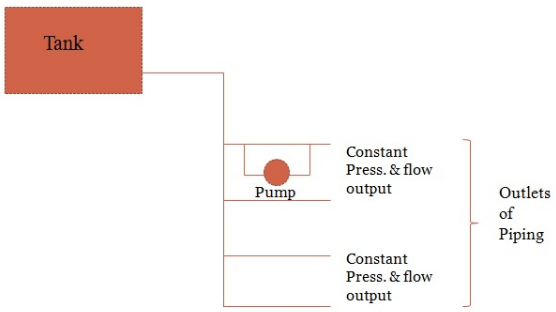

Fig.7 Block Diagram of Booster system

7 Method of Calculation

The Life Cycle Cost (LCC) analysis is a tool that can help minimise waste and maximise energy efficiency for many types of systems, including water boosting systems. Like buildings, booster systems vary greatly in size and design, making it difficult to determine which is most efficient. In this fictitious case study, we will look at four different system configurations. We will look into their pros and cons allowing you to see which the most economical choice in this example is.

The 20-year life cycle cost calculation (LCC), includes the initial investment in the booster systems, pipes and tanks, as well as energy costs, lost revenue costs, and maintenance costs.

Life cycle cost calculations for pumping systems are normally conducted with only three parameters taken into account.

These observable costs are:

- Initial cost of booster sets
- Maintenance costs
- Energy costs

$$LCC = Cib + Cip + Cm + Ce + Cr$$

Where,

LCC = Life cycle cost

Cib = Initial cost for booster sets

Cip = Initial costs for piping, pressure reduction valves and tanks

Cm = Maintenance costs

Ce = Energy costs

Cr = Lost revenue costs

Initial cost for booster sets, Cib

This includes a booster set or pumps and all the equipment and accessories needed to operate the booster sets:

- Pumps
- Frequency converters
- Control panels
- Pressure sensors
- Diaphragm tanks

Initial costs for tanks and pipes, Cip

In tall buildings, capital costs for piping, valves and tanks often exceed the costs for boosters many times over. This case study is no exception.

The calculation of costs includes:

Vertical riser pipes including pipe insulation, pipe bearings and mounting.

Maintenance costs, Cm

Maintenance over a 20-year period:

Maintenance of booster sets is estimated to constitute 50% of the booster's initial purchase price.

- Pipes and PRVs: 5% of the initial investment
- Roof and break tanks: 20% of the tank's initial cost

Energy costs, Ce

The energy calculations are performed according to the formula shown below.

$$E1\ [kWh] = \frac{Q\ [m^3/s] * H\ [kPa] * h\ [h]}{\eta\ [-]}$$

The table on the right shows the principle of all energy calculations. The annual energy consumption is calculated on three duty points.

Lost revenue, Cr

As real estate becomes more valuable, the amount of saleable area gets more and more important. In many instances it is profitable to extend the height of a building. Another and more effective way to increase the saleable area is to reduce "wasted" space for building services. In this calculation, the value of the space that boosters and break tanks take up is taken into account.

Revenue costs may vary according to individual market conditions.

8 Why Pressurized System

1. Creating flow in the water system consumes power and so does creating pressure even when there is little or no flow. Therefore, booster configurations with several booster sets and low pressure levels are preferable as the power consumption will reduce significantly as the provided pressure reduces. The systems (2, 3 and 4) are divided into pressure zones of a maximum of 12 floors. The maximum geometric height is limited to 50m or 5 bar in each zone. Since the required pressure is low compared to the single booster system (1) and the roof-tank system (3) the power consumption is lower. In system 1 the total amount of water (295m3/day) is pressurised to 29 bar which makes the use of pressure reduction valves necessary. The pressure of the zone divided systems (4) is as low as 6 bar and hence no PRVs are necessary. The roof-top tank system

turns out overall, to be the least profitable system and its power consumption to be the highest of all systems. This is surprising as the booster set is allowed to operate at a constant flow of 15m3/h for 20 hours a day.

2. The consumption profile shows that water demand changes during the day. Constantly adapting to the flow requires booster sets and a pipe system sized for the peak flow whenever it occurs. In tall buildings, zone divided water boosting systems should always be considered the preferred water supply. The result is significantly lower power consumption because the boosters are running at lower pressure levels. A zone divided system will even make pressure reduction valves obsolete as the static pressure is kept at a low and acceptable level. This ensures increased end-user comfort.

3. Energy savings is crucial- Traditionally, there has been great focus on initial cost both when choosing booster sets and when settling for a system configuration of boosting systems. The calculation shows that doing so is unwise. However, it is a fact that zone divided systems call for increased investment in booster sets, but this study shows that investment in boosters is of minor importance in the longer term. Focus should be given to the entire boosting configuration as energy consumption is the most important element to consider: energy consumption turns out to account for more than all the remaining costs added together.[6]

9 Conclusions

Maintaining pressure and flow of water in multi storey building is necessary as required water pressure for both fire-fighting and domestic use increased and mains water was insufficient to supply a whole building. Hence to maintain constant pressure and flow by using Pressurised system of Booster pumps.

- Pressurised booster system can decrease operational cost as it consumes less power.
- Using this system we can omit roof tank, this leads to decrease construction cost of tank and also no specially allotted space is required for the roof tank.
- For system like Series connected system and Zone divided system required low pressure in each zone thus this pressure is manageable and also low pressure grade pipes are required which decrease initial cost of the system.
- But as Pressurised booster system is completely depends on pump, it vulnerable in case of pump failure.
- Also it works only on electric power, system fails if electric fall out is occurs.

As the analysis shows, the pressurised series – connected system and zone divided systems are superior to the roof-top tank solutions - both when it comes to initial investment, maintenance and energy efficient operation.

10 Acknowledgement

We would like to thank RSSOER (JSPM NTC) and BSSOER (TSSM's) Mechanical Dept. for their support our work.

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